RESPONSE–SELECTION IN DISCRIMINATIVE LEARNING

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In a recent issue of this JOURNAL (13) Nissen contrasts two sets of terms which have been used to describe the behavior of animals in discrimination-situations. One set of terms is response-oriented; the animal is reported to "turn to the right" or to "turn to the left" in the presence of a given pattern of stimuli. This description implies that each spatial arrangement of the stimuli to be discriminated constitutes a discrete configuration for which the animal must select an appropriate response. The second set of terms emphasizes the acquisition of functional significance by afferent components and ignores the precise character of the movements involved in the solution of the problem; the animal is reported to "approach" one stimulus and to "avoid" the other. As Nissen remarks, "Even introspective evidence suggests a critical difference: 'reaching towards the right' (when green happens to be at the right, red at the left), is not the same thing as 'approaching (or reaching towards) green'" (13, p. 121).

Nissen recognizes that, for higher organisms at least, both terminologies may find application (according to the nature of the discrimination-problem in question), but he is inclined to believe that the approach-avoidance formula-

interpretation which he defends. A group of animals was trained to obtain food in an apparatus which presented black and white cards in an up-down relation (one above the other). The task of the animals was to select one of the two cards on each trial irrespective of whether it appeared in the upper or lower position. Other animals were trained in the same manner except that the cards appeared only in a right-left relation. When the animals of each group had reached the criterion of learning, they were shifted to the problem of the other group. That is to say, animals trained in the right-left situation were shifted to up-down, and conversely. Computations by the method of savings revealed a large amount of transfer from problem to problem (66 to 100 per cent), and Nissen concludes that these results can be accounted for only in approach-avoidance terms.

It must be noted, however, that Nissen's results are not unambiguous. Certainly one cannot dispute his interpretation of the behavior of animals showing 100 per cent transfer. Clearly these animals had learned something which was relatively independent of motor functions. As Nissen suggests, perfect transfer can only be explained if we schematize the learning as

^{S}black—^{R}approach ^{S}white—^{R}avoidance

rather than as

^{S}black-white—^{R}left ^{S}white-black—^{R}right.

tion will cover all cases of discriminative learning. Nissen describes an experiment with chimpanzees which may seem to suggest both the validity of the distinction which he emphasizes and the

But what can be said of animals showing only intermediate amounts of transfer? Some disturbance was produced either by the changed perceptual configuration, *qua* percept, or by the change

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in the appropriate response, or both. Instances of less than complete transfer deprive the approach-avoidance formulation of complete generality.

The most explicit statement of the response-oriented interpretation of discriminative learning is to be found in the position of Gulliksen and Wolfle (5, 6). These writers maintain that each spatial arrangement of stimuli in a two-choice problem (e.g., black-left/white-right and white-left/black-right) must be considered as a discrete configuration, and that the process of learning such a problem is essentially a process of selecting the response appropriate to each configuration. Although the evidence which Gulliksen and Wolfle present in support of this interpretation is not crucial, a recent experiment by Bitterman and Coate (2) has incidentally provided supporting data. In learning a brightness-discrimination on the black and white alleys of an elevated maze, the rats of Bitterman and Coate showed a significant tendency to master each spatial arrangement of the alleys at a different rate depending upon the nature and frequency of their experience with each situation in an earlier stage of training. If, as Nissen suggests, the animal learns only to approach one of the two stimuli and avoid the other, their spatial relation should make no difference—a deduction which is, in fact, the basis of his own experiment.

The position of Gulliksen and Wolfle has been severely criticized by Lashley (7) who presents convincing evidence for its lack of complete generality. Lashley trained rats in a three-choice discrimination-situation, with three circles differing in size as stimuli. His animals could master the problem when the largest circle was positive or when the smallest circle was positive, but not when the intermediate circle was positive. Since all three problems involve the same six spatial arrangements of

the stimulus-cards and the same three responses (jumping to left, to right, or to center), the only difference being in the pairings of stimulus-arrangement and response, the view of Gulliksen and Wolfle does not make it possible to account for the failure of the animals to master the intermediate-size problem.

We have noted thus far that both formulations under examination are confronted with certain difficulties. Lashley's results with the three-circle problem cast doubt upon the general validity of the Gulliksen-Wolfle position,[1] and the approach-avoidance position, as formulated by Nissen, cannot deal with the evidence of situational learning provided by Bitterman and Coate, or with instances of less-than-complete spatial transposition reported by Nissen himself. But while Lashley's evidence is crucial, and undeniably limits the applicability of the theory of Gulliksen and Wolfle, Spence's elaborate and ingenious version of the approach-avoidance position (15) is not contradicted by the data considered up to this point.

Spence's theory falls rather clearly into Nissen's approach-avoidance category. As Spence has written: "Discrimination learning does not consist . . . in the strengthening of one response relatively to another or others as in the case of problem-box learning, but involves, rather, the relative strengthening of the excitatory tendency of a certain component of the stimulus complex as compared with that of certain other elements until it attains sufficient strength to determine the response" (15, pp. 429–430). The central assumption of Spence's theory is that discrimination is the end-product of a continuous, cumulative process of ac-

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[1] There is other evidence which contradicts the position of Gulliksen and Wolfle. Lashley's succinct criticism serves only as an example of the sort of difficulty with which the theory is faced.

quisition of excitatory and inhibitory characteristics by components of the stimulus-situation. Consider, for example, a black-white problem which requires the animal to go to white irrespective of its lateral position. The course of discrimination may be described in terms of four principal afferent components, two of which are relevant (blackness and whiteness) and two of which are irrelevant (rightness and leftness). These components may have certain excitatory and inhibitory values even before the animal makes the first response (presumably derived from its previous experience). Suppose that the first trial is to black-left/white-right. If the combined excitatory values of blackness and leftness minus their combined inhibitory values exceeds the combined excitatory values of whiteness and rightness minus their combined inhibitory values, the animal will go to black-left (non-reinforced), thus increasing the inhibitory values of blackness and leftness. As the training continues (under conditions of spatial alternation) the irrelevant components are inconsistently reinforced, whiteness is consistently reinforced, and blackness is never reinforced, until the black-white difference exceeds whatever difference may exist between irrelevant components, at which time the problem is solved.

This theory can readily account for certain instances of situational learning in discrimination-problems. If, as in the experiment of Bitterman and Coate, the animal comes to the black-white problem with a position bias (a marked difference in the excitatory values of leftness and rightness), the spatial arrangement which presents the positive stimulus on the preferred side will be mastered more readily than the reverse arrangement. Spence's theory would also lead us to expect cases of less-than-perfect transfer in Nissen's experiment.

Preëxisting differences in the excitatory values of rightness and leftness might cause difficulty for an animal shifted from the up-down problem to the right-left problem, and conversely.

Although most of the experimental work on discriminative learning has been done with problems of the *simultaneous* kind, in which two different stimuli are presented contiguously and the animal is required to choose one of the pair irrespective of spatial arrangement, another method is available which has crucial bearing on the problem at hand. Suppose that the stimuli to be discriminated are presented *successively*. For example, in a T-maze discrimination-apparatus the animal may be required to turn to the right when a tone of one pitch is sounded and to the left when a tone of a second pitch is sounded (12); or, the animal may be required to turn to the right when two white alleys are presented and to the left when two black alleys are presented (9, 10). Nissen recognizes that the ability of animals to master such problems poses a difficulty for approach-avoidance theory, which he attempts to save by assuming that such learning involves a complex, conditional type of solution. "The fact that such problems are in general learned with relative difficulty," he remarks, "is in keeping with this interpretation" (p. 129). Actually, however, there has been no systematic study of the relative difficulty of simultaneous and successive discrimination bearing on the theoretical question under consideration.[2] Such a study would pro-

[2] Grice (4) has used the terms "simultaneous" and "successive" in a somewhat different sense. His experiment was designed to study the effects of opportunity for direct comparison of the stimuli to be discriminated. Both of the problems mastered by his animals can be dealt with in simple approach-avoidance terms.

vide a crucial test of the approach-avoidance formulation.

The experiment to be reported was designed to compare the relative difficulty of simultaneous and successive light-dark discrimination-problems. At each choice-point in a four-unit alley maze, one group of animals encountered one lighted alley and one darkened alley. The task of these animals was to go either to dark or to light irrespective of lateral position. A second group of animals found either two lighted alleys or two darkened alleys at each choice-point and were required to turn in one direction in the first case and in the opposite direction in the second. Nissen has already predicted that the second problem should be more difficult, and Spence's position leads to the same prediction. If stimulus-components acquire functional properties *independently* and function together only in a *summative* manner, an animal confronted with the second problem must be expected, on any trial, to approach the preferred side (irrespective of the brightnesses presented at each choice-point) if there is a position preference, and either side at random if there is not. Learning cannot take place because there is no stimulus-component which is consistently reinforced or non-reinforced.[3] Lashley must also predict that the simultaneous problem should be easier, not only because it does not require a conditional solution but also because it provides the animal with opportunity for direct comparison of the stimuli to be discriminated (8). Only a theory such as that of Gulliksen and Wolfle leads to the prediction that the successive problem will be less difficult. The two configurations presented in the

simultaneous problem (light-left/dark-right and dark-left/light-right) are probably more similar to each other and therefore should be more difficult to distinguish than those presented by
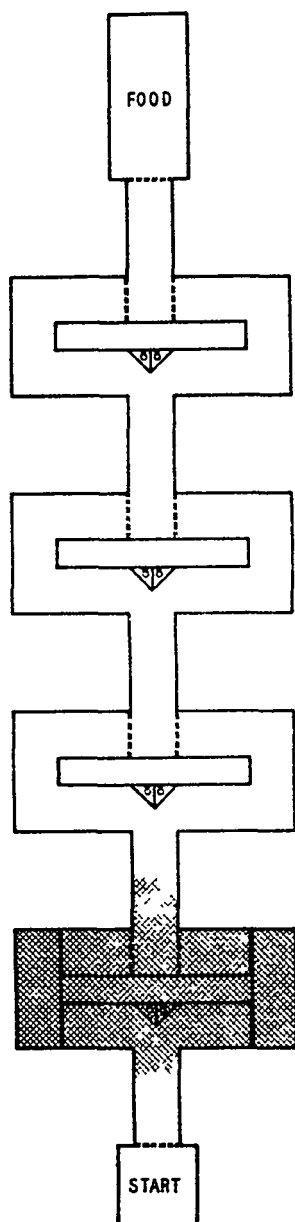

FIG. 1. Diagram of the apparatus.

[3] Mastery of the problem can be accounted for in terms of afferent neural interaction, but the extensive training required for stimulus-compounding leads to the prediction that the simultaneous discrimination will develop at a more rapid rate than the successive.

the successive problem (double-light and double-dark). The results of the experiment to be reported are in accord with this prediction.

APPARATUS AND PROCEDURE

The apparatus employed, which is illustrated in Fig. 1, was a modification of Stone's multiple discrimination-box (16). It consisted of a starting-box (8″ × 8″), a food-box (8″ × 17″), and four identically constructed discrimination-units, each incorporating a separate choice-point. Each alley was 12″ long and 4½″ wide. All walls were 4½″ high. The entire apparatus was painted flat black and the top was uniformly covered with heavy-gauge hardware cloth. The apparatus had no floor, but was set on a sheet of black oilcloth which could be cleaned easily. The essential details of construction are indicated in Fig. 1. The hatched lines represent the hardware cloth top. The solid double lines drawn only in the first unit represent black metal bars used to support the sides. The double broken lines drawn at the starting-box and food-box show the positions of guillotine doors operated by the experimenter from a position just back of the starting-box by means of a string and pulley system. The double broken lines in each discrimination-unit indicate the points at which partitions could be inserted in order to convert either alley into a cul. Each choice-point contained two 7½ w., 115 v. lamps separated by a white partition which functioned as a reflector. The lamps were set in a V-shaped housing of clear plate-glass. Diffuse, indirect light from a fixture 6′ above the center of the maze dimly illuminated all of the alleys, thus permitting the animals to see the interior of the apparatus. Nevertheless, when one of the two lamps at a given choice-point was on and the other off, a sharp difference in the brightness of

the alternative pathways was produced. The experiment was conducted in the Dome Room of the animal laboratory at the University of Texas.

Twenty naïve albino rats ranging in age from 85 to 100 days were employed. The animals were divided into two groups. Group I, consisting of six males and four females, learned the simultaneous problem, and Group II, five males and five females, learned the successive problem.

In the simultaneous problem, one lamp at each choice-point was on and the other was off. The task of the animals was to turn either in the direction of the lighted alley or of the darkened alley at every choice-point. Half the animals of Group I were required to go to light and half were required to go to dark. An incorrect turn at any choice-point led to a barrier, while a correct turn led to subsequent choice-points and eventually to the food-box. On each trial the stimuli were so arranged as to require two right turns and two left turns. There were six possible turning orders (RRLL, RLRL, RLLR, LLRR, LRLR, and LRRL), which were employed equally often in random fashion on successive trials. At each choice-point, therefore, the animal was required to go right on half the trials and left on half the trials, depending on which of the two lamps was lighted.

In the successive problem, the lamps at each choice-point were either both on or both off. Half the animals of Group II were required to go right to double-light and left to double-dark, while the other half of the animals were required to respond in the reverse manner. As in the simultaneous problem, of course, an incorrect turn led to a barrier, while a correct turn led to subsequent units and finally to the food-box. Again, the stimuli were so arranged that the animals were required

to make two right turns and two left turns on each trial. The same turning orders were employed as for the simultaneous problem, and trials were matched so that animals of both groups were required to make the same sequence of turns on any given trial.

Throughout the experiment the animals were kept on a 24-hour feeding schedule. During the first three days the animals were placed in the food-box and allowed to eat for several minutes. The apparatus was then set up in such a way that only one discrimination-unit separated the starting-box from the food-box, and on the fourth day the groups were given six trials in the one-unit apparatus. The choice-point presented the same arrangements of stimuli to each animal as it would encounter in the main part of the experiment, and responses were reinforced in a manner

appropriate to the problem subsequently to be learned by the animal. On the fifth day, training in the four-unit apparatus was begun. Four trials per day were given and each animal was run to a criterion of four successive errorless trials (16/16 correct choices). At the conclusion of each trial the animal was allowed a 20-second period of feeding in the goal-box.

RESULTS AND DISCUSSION

The course of learning in the two groups is shown by the curves of Figs. 2 and 3. As each animal reached the criterion, its training was terminated, but for the purpose of plotting these curves it was assumed to have continued to make perfect runs on succeeding days. Figure 2 shows mean errors per trial per day for each of the two groups, retracing errors being considered along
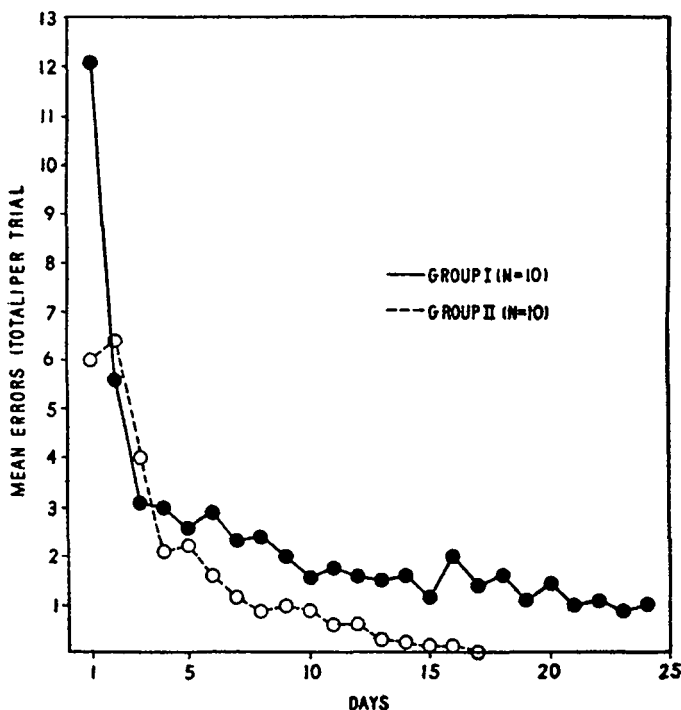

FIG. 2. The course of learning plotted in terms of total errors per trial per day. Group I, simultaneous; Group II, successive.
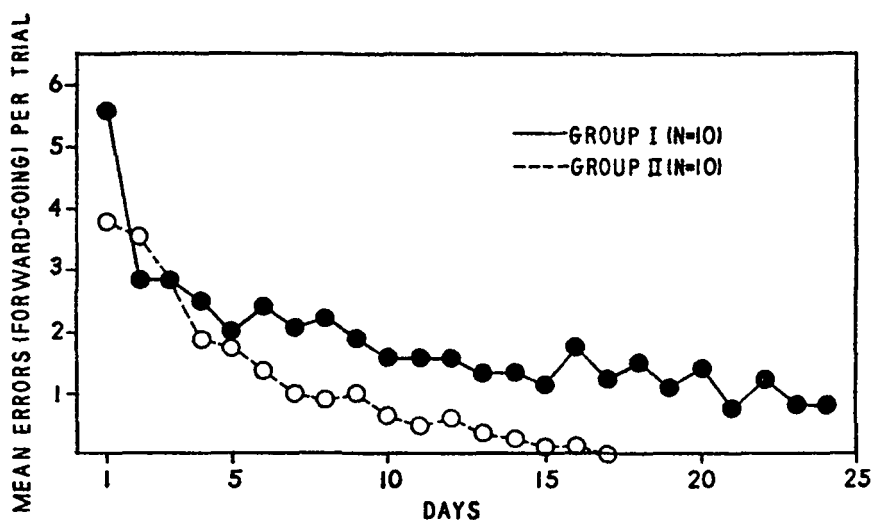
FIG. 3. The course of learning plotted in terms of forward-going errors alone.
Group I, simultaneous; Group II, successive.

with forward-going entries into blinds. Both groups retraced considerably during the first few days, which accounts for the fact that the early sections of both curves rise high above two errors per trial, the chance expectancy based on four choice-point encounters. Retracing errors were eliminated early in Group II but continued for some days in Group I. Figure 3 is plotted in terms of forward-going errors alone and shows more clearly the course of learning of the discrimination-problem *per se* in each group. In this curve, again, the higher error score of Group I is in part a function of a greater tendency to retrace, since this group approached the discriminanda more frequently on each trial and thus had greater opportunity for error.

Results for trials and forward-going errors alone, are summarized in Tables 1 and 2. The differences between the two groups are so large that relatively crude, non-parametric statistical techniques are sufficient to indicate their significance. Group II (the successive group) reached the criterion of mastery (one perfect day) in a mean of 48.8

trials and 78.7 errors. The last animal of this group to learn reached the criterion on the 17th day, the same day on which the first animal of Group I reached the criterion. By the 24th day, at which time the experiment was terminated, only three animals of Group I had mastered the simultaneous problem, although all animals in the group were showing signs of learning. The ranking method of Wilcoxon (18) indicates the difference between the two groups in trials and in errors to be significant at better than the one per cent level of confidence.

Even if we consider errors made on the first approach to each choice-point on each trial, the two groups are still sharply separated and the differences in error scores remain significant at better than the one per cent level. From this evidence it seems safe to conclude that the difference in amount of retracing is a *result* rather than a *cause* of the difference in difficulty between the two problems.

A possible explanation of the difference between the simultaneous and successive problems is suggested by the

principle of secondary reinforcement. It might be argued that since the illumination of the goal-box corresponded to that of the darkened alleys, darkness might have acquired secondary reinforcing properties. If such were the case, the five animals trained to go to light as opposed to darkness would be placed at a disadvantage. By the same token, however, the animals trained to go to darkness should have a considerable advantage, not only over the animals trained to light, but also over the animals of Group II for which this factor could not have significance. Analysis of the data shows that the dark-positive animals of Group I (Numbers 6–10) did, on the whole, make fewer forward-going errors than the light-positive animals (Numbers 1–5) of that group, although the difference is not statistically significant. Even the performance of the dark-positive animals, however, was significantly inferior to that of the animals of Group II, at the one per cent level of confidence by Festinger's method (3).

The implication of these results is clear. The approach-avoidance formulation will not serve as a general principle of discriminative learning, but must be supplemented with a principle which takes into account the development of differential response to discrete spatial configurations of stimuli. The behavior of some of Nissen's animals (those showing 100 per cent transfer) and the performance of Lashley's rats on the three-circle problem demonstrate the necessity for something like an approach-avoidance principle, but the results of the present experiment point to a qualitatively distinct functional level which may be more primitive. There is no way to determine the manner in which the simultaneous problem was learned by the animals of Group I which achieved the criterion. If learned configurationally, the greater difficulty of the simultaneous problem may be attributed to the greater similarity of the two stimulus-patterns which it presented to the animal, as the theory of Gulliksen and Wolfle suggests. If mas-

TABLE I

TRIAL SCORES FOR EACH ANIMAL OF EACH GROUP *

Group I (simultaneous)			Group II (successive)		
Animal	Score	Rank	Animal	Score	Rank
1	100	17	11	48	5
2	100	17	12	68	10.5
3	100	17	13	52	6.5
4	96	13	14	36	2
5	100	17	15	44	4
6	100	17	16	52	6.5
7	100	17	17	32	1
8	88	12	18	40	3
9	100	17	19	60	9
10	68	10.5	20	56	8
Total	952	154.5		488	55.5
Mean	95 2			48.8	
Mean difference		46.4**			

* A trial score of 100 was assigned to those animals (Group I) which failed to reach the criterion on the 24th day, at which time training was terminated.

** Significant at better than the one per cent level of confidence (Wilcoxon's method).

TABLE II

FORWARD-GOING ERROR SCORES FOR EACH ANIMAL OF EACH GROUP *

Group I (simultaneous)			Group II (successive)		
Animal	Score	Rank	Animal	Score	Rank
1	164	16	11	69	5
2	157	15	12	117	11.5
3	123	13	13	102	9
4	196	19	14	39	1
5	209	20	15	62	3
6	188	18	16	101	8
7	174	17	17	54	2
8	136	14	18	65	4
9	117	11.5	19	92	7
10	109	10	20	86	6
Total	1573	153.5		787	56.5
Mean	157.3			78.7	
Mean difference		78 6**			

* Error scores are based on 24 days of training irrespective of whether or not an animal reached the criterion on or before this day.

** Significant at better than the one per cent level of confidence (Wilcoxon's method).

tery was based on the acquisition of functional properties by afferent components, this kind of learning may be assumed to involve a more complex, higher order process. In any event, present evidence suggests that two qualitatively distinct processes of learning may operate in discrimination-situations. It is interesting to note the relation between this conclusion and the two-factor conception of modifiability advanced by Maier and Schneirla (11) and by Birch and Bitterman (1). The two processes which seem to operate in discrimination-situations closely resemble the two processes designated by these writers as "sensory integration" and "selective learning." The only discrepancy seems to lie in answers to the question as to which is the more primitive.

The relation between the present results and those of certain previous experiments on the problem of relational learning should also be considered. Lashley and Wade (8) have maintained that opportunity to compare the stim-

uli to be discriminated facilitates learning. Grice's experiment (4), which was designed to test this hypothesis, failed to show an advantage for the "comparison" group. Another method employed by Saldanha and Bitterman (14) did, however, give a clear advantage to the comparison group under certain conditions. These writers suggest that opportunity for comparison may facilitate learning only when the stimuli to be discriminated are relatively similar. The fact that the simultaneous group of the present experiment, which was provided with opportunity for direct comparison, was surpassed by the successive group, which had no opportunity for direct comparison, may be a function of the great dissimilarity between the two brightness levels employed. It is interesting to ask what would happen in an experiment similar to the present one in which two closely similar brightness levels were employed. It would follow from the position of Saldanha and Bitterman that the simultaneous group should surpass the suc-

cessive group. That is, opportunity for comparison would give an advantage to the former group which would offset the greater fundamental simplicity of the successive problem.

At the outset of the present paper the Gulliksen-Wolfle theory was designated a response-oriented conception in order to differentiate it from the approach-avoidance formulation in the simplest possible manner. Implicit in the discussion of the two orientations, however, was another distinction which may be phrased in afferent terms. For Gulliksen and Wolfle, stimulus-components do not acquire functional significance independently or in isolation, but are integrated to form a functional unity which may comprise spatial as well as other attributes of the part-processes. We might term this intra-situational integrating process *configurational* perception and reserve the term relational perception for the abstractive, trans-situational or trans-contextual process which is emphasized in Lashley's theory. That the two criteria—afferent and efferent—for distinguishing between the formulations with which we began cannot be treated as separate items in a list is suggested by the evidence which Werner has compiled in his stimulating work on mental development (17). Werner, himself, finds it necessary to postulate several genetically distinct discriminative processes, the most primitive of which he refers to as "syncretic" organization in which sensory and motor components are diffusely and inextricably inter-related.

SUMMARY

The question of the relative ease of simultaneous and successive problems has considerable bearing on the validity of current theories of discriminative learning. An experiment is reported in which a group of rats were trained in a multiple discrimination-apparatus to choose the brighter or darker of two alleys (simultaneous problem) while a second group of rats were trained to turn in one direction when both alleys were lighted and in the opposite direction when both were dark (successive problem). The first problem proved to be significantly more difficult than the second. This result is interpreted to mean that under certain conditions the process of discrimination cannot be appropriately described in approach-avoidance terms, but requires the assumption that the animal learns to respond differentially to discrete spatial configurations of stimuli. Taken together, the data presently available suggest the operation of two qualitatively distinct levels of perceptual organization in discriminative learning—a concrete, primitive, intra-situational level and a more abstract, selective, trans-contextual one. The first level is intimately related to motor functions while the second may be largely independent of them.

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